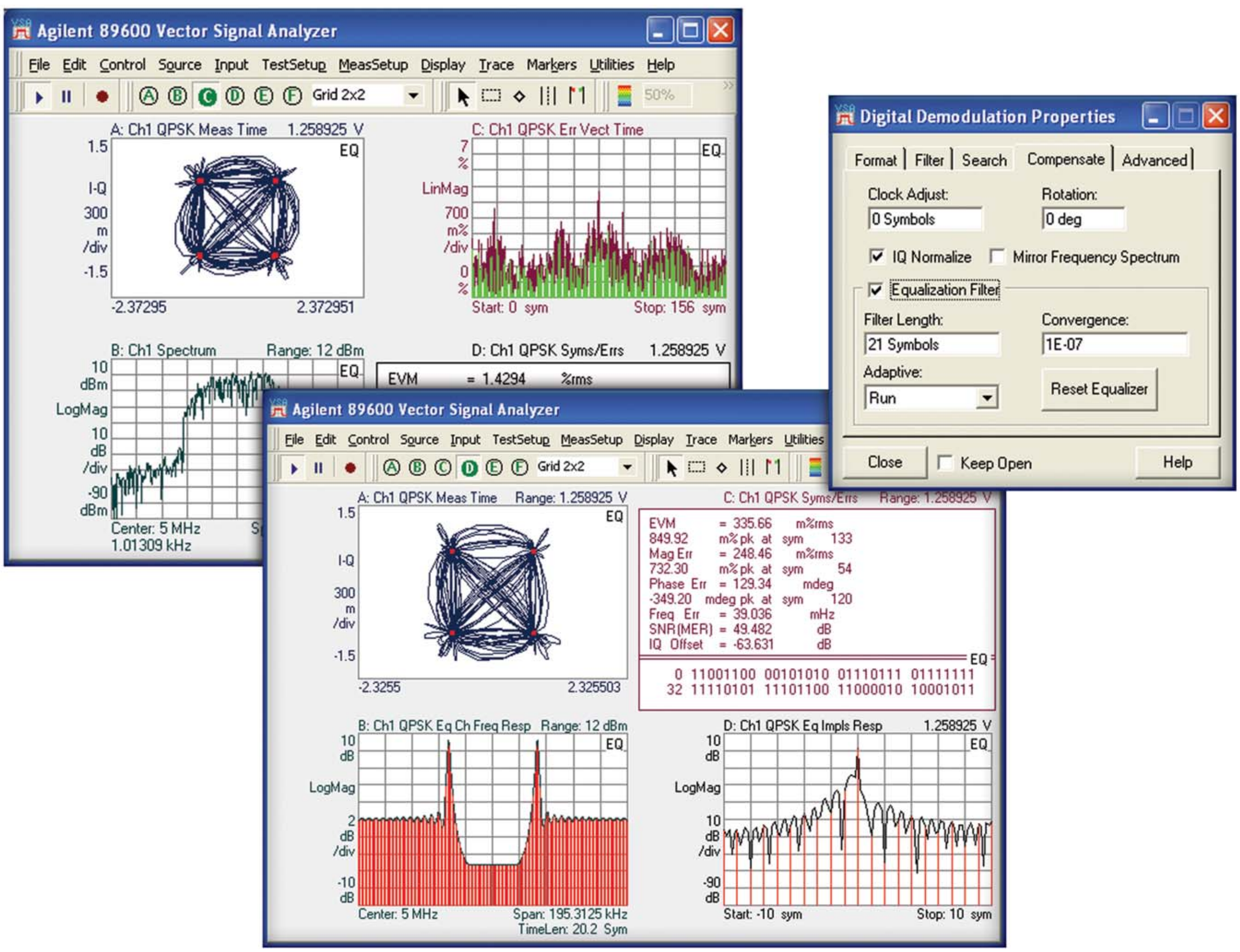
Agilent 89600 Vector Signal Analysis Software
Option AYA: Flexible Modulation Analysis

Focus on Adaptive Equalization

Self-Guided Demonstration



Agilent Technologies

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Adaptive Equalization Overview

Adaptive equalization is an important tool for today's receivers. It is required by standards such as IEEE 802.16e (Mobile WiMAX™). Adaptive equalization is also useful for analyzing signals as it allows you to remove propagation effects from measurements and separates linear errors from non-linear errors. Determining whether your errors are linear or non-linear can provide useful troubleshooting information in and of itself. Adaptive equalization is a useful tool for identifying linear errors.

Linear errors include:

- Group delay distortion
- Frequency response errors (tilt, ripple)
- Reflections or multi-path distortion from IQ modulated signals
- DSP errors in miscoded bits, or incorrect filter coefficients

Non-linear errors include:

- Noise
- Spectral regrowth or adjacent channel interference
- Intermodulation
- Spurs
- Harmonic distortion

The most common types of equalizers are feed-forward and decision feedback. Figure 1, below, shows the process that each of these equalizers uses to compute the filter coefficients.

Feed-forward equalization uses an equalization filter, before applying any other static measurement filters that are in place. The signal is then demodulated and measured. After measurement, the equalization filter is modified to adjust for additional changes.

In decision feedback equalization, the static measurement filters are applied first, then combined with the output of the previous cycle. In this method, the modulator will ideally output a noise-free signal, so that the equalization process itself does not add any additional noise to the signal.

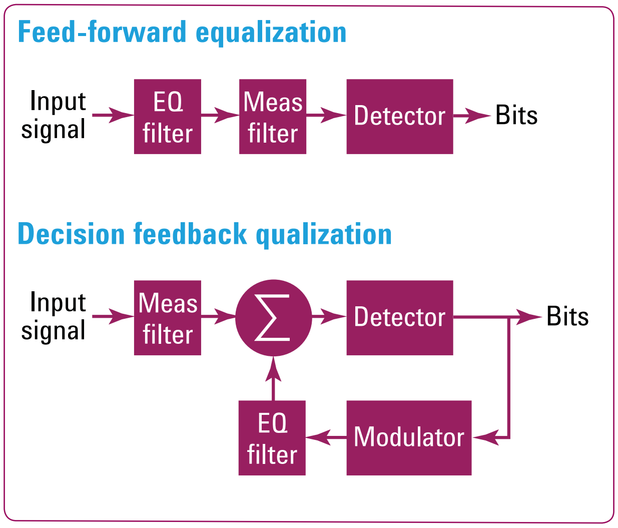

Figure 1. Predominant types of equalization.

There are also two types of equalizer training techniques: one uses training sequences embedded in the signal, and the other, called blind equalization, does not. Figure 2, below, shows the block diagram representation for these equalizer training techniques. While blind equalization works without any prior knowledge of the signal, it can be slow to converge if a lot of bit errors are present. Slow convergence makes the equalizer less responsive to rapidly changing channel conditions. Most equalizers use training sequences. The signal must include this sequence, and throughput is therefore reduced. The trade-off is that the equalizer is able to converge quickly, even in the presence of many bit errors.

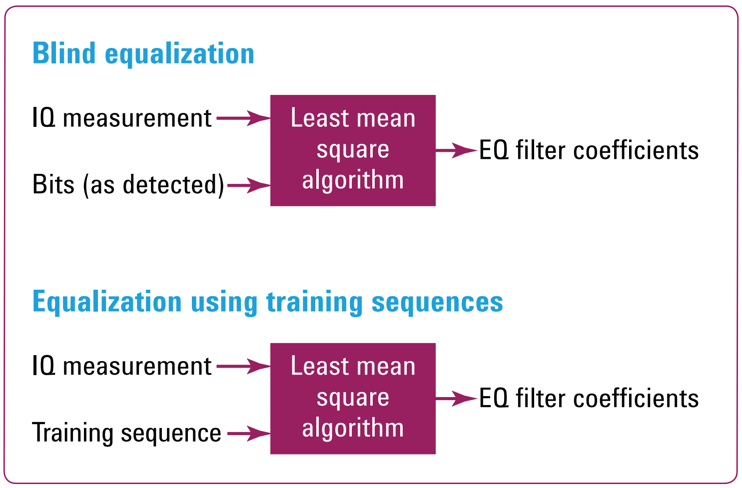

Figure 2. Equalizer training techniques.

The 89600 VSA software uses a feed-forward equalizer type, with a blind equalization training technique. This provides a universal equalizer setup that accommodates a wide range of signal types. This demonstration guide discusses the equalizer in the 89600 VSA Option AYA vector modulation analysis software. Additional demodulation options which use equalization are available for: WLAN, WLAN-MIMO, WiMAX, and Mobile WiMAX. There are however, several key differences in how equalization is used in Option AYA digital demodulation and these other options:

- Option AYA computes Channel Frequency Response (explained in more detail below) by comparing the IQ Meas Time and IQ Ref Time data, while the formats listed above compute it from a training sequence, the preamble/data.
- Option AYA uses averaging when computing the equalizer frequency response. The format options compute a new equalizer response for each data burst.
- Option AYA allows the equalization filter to be disengaged. The other format options cannot be disabled.

Further information about these topics can be found in the **Help** section of the 89600 VSA Software.

System Requirements

Table 1, below, describes the minimum hardware requirements for running the 89600 VSA software.

Table 1. System requirements

Characteristic	Microsoft® Windows® XP Professional	Microsoft® Windows® Vista Business, Enterprise, or Ultimate
CPU	600 MHz Pentium® or AMD-K6 > 600 MHz (>2 GHz recommended)	1 GHz 32-bit (x86) or 64-bit (x64) (>2 GHz recommended)
Empty slots (desktop)	1 PCI-bus slot (Two recommended – VXI hardware only)	1 PCI-bus slot (Two recommended – VXI hardware only)
Empty slots (laptop)	1 CardBus Type II slot (Integrated FireWire® recommended for VXI hardware only)	1 CardBus Type II slot (Integrated FireWire® recommended for VXI hardware only)
RAM	512 MB (1 GB recommended)	1 GB (2 GB recommended)
Video RAM	4 MB (16 MB recommended)	128 MB (512 MB recommended)
Hard disk	512 MB available	512 MB available
Additional drives	CD-ROM to load the software; license transfer requires a 3.5 inch floppy disk drive, network access, or USB memory stick	CD-ROM to load the software; license transfer requires a 3.5 inch floppy disk drive, network access, or USB memory stick
Interface support	LAN, GPIB, USB, or FireWire[1] interface (VXI HW only)	LAN, GPIB, USB, or FireWire[1] interface (VXI HW only)

Table 2, below, describes the 89600 VSA software requirements to use this demonstration guide. If you do not already have a copy of the software, a free trial version can be downloaded at **www.agilent.com/find/89600**.

Table 2. Software requirements

Version	89600 version 1.0 or higher (89601A, 89601AN, 89601N12) – Note: substantial improvements to the options listed below have occurred since version 1.0, and customers are encouraged to use the latest version. Existing 89600 VSA customers can order the 89601AS/ASN software update subscription service to upgrade to the latest version.
Options	(89601A, 89601AN only)
• 200	Basic vector signal analysis
• 300	Hardware connectivity (required only if measurement hardware will be used)
• AYA	Vector modulation analysis

1. For a list of supported IEEE-1394 (FireWire) interfaces, visit www.agilent.com/find/89600 and search the FAQ's for information on "What type of IEEE-1394 interface can I use in my computer to connect to the 89600S VXI hardware?"

Setup

This note is written as a guide to using the 89600 Series VSA software for making adaptive equalization measurements. More information about the topics discussed can be found in the help text documentation included with the software by clicking the **Help** button on the main toolbar menu.

Recall sample signal

The instructions listed in Table 3 recall the signal used in the first portion of this demonstration. Your display should look similar to Figure 3. This is a QPSK signal with a center frequency of 5 MHz and a nominal span of 156.25 kHz.

Table 3. Recall recorded sample signal

Instructions	Toolbar menus
Preset the software	**File > Preset > Preset All** *Note:* Using **Preset All** will cause all saved user state information to be lost. If this is a concern, save the current state before using **Preset All.** Click **File > Save > Setup**
Go to the default signal directory (C:\Program Files\Agilent\89600VSA\Help\Signals)	**File > Recall > Recall Recording**
Select the Qpsk.dat signal	Select **Qpsk.dat** Click **Open**
Start the measurement	Click ▶ (toolbar, left side)

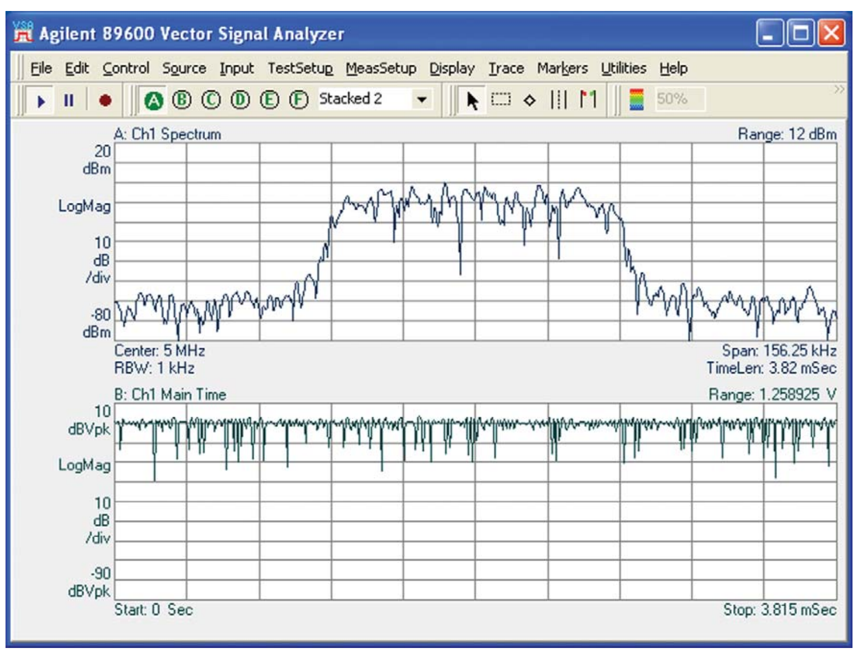

Figure 3. Recalled recorded signal.

For best results, the center frequency, span, range, etc. should be set to their correct values for the signal you are using.

Starting Digital Demodulation

To work with adaptive equalization, the analyzer must be in digital demodulation mode. Table 4, below, describes the method for setting up digital demodulation, and Figure 4 shows the resulting display.

Table 4. Setting up digital demodulation

Instructions	Toolbar menus
Select demodulation type	**MeasSetup** > **Demodulator** > **Digital Demodulation**
Change display setting	**Display** > **Layout** > **Grid 2x2**
Set up the demodulator	**MeasSetup** > **Demod Properties** Click on the **Format** tab
Set the format parameters	Click the drop-down arrow for the **Format** and select **QPSK** In the **Symbol Rate** box type **50** and select **kHz** from the drop down box
Set the search parameters	Click on the **Search** tab Uncheck the box next to **Pulse Search**

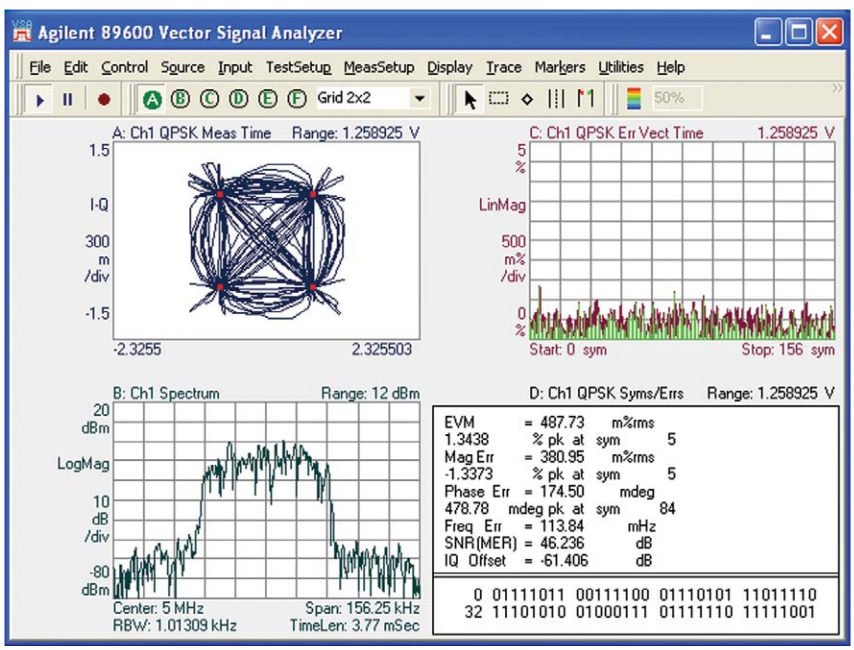

Figure 4. Digital demodulation for Qpsk.dat signal.

Adaptive Equalization

Filter parameters

Table 5 describes turning off the measurement filter for the **Qpsk.dat** signal, and replacing it with the equalization filter. Figure 5 shows the resulting display. The 89600 VSA software provides several standard measurement and reference filters that can be used with your signals. The current correct measurement filter for the **Qpsk.dat** signal is a Root Raised Cosine or Nyquist filter. This filter produces excellent EVM results. However, for the purpose of this demonstration, we will replace the standard filter with the adaptive equalizer.

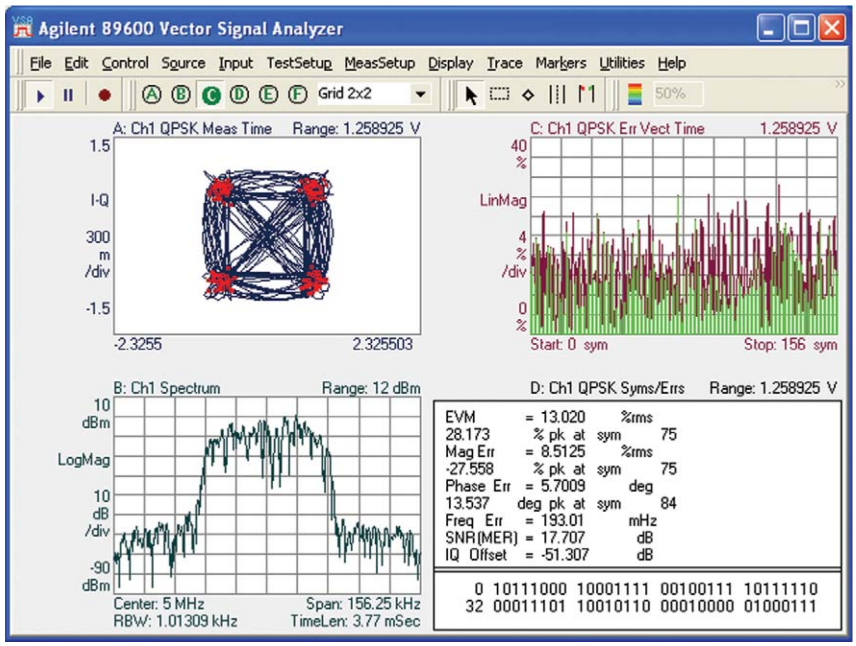

Figure 5. Qpsk.dat signal with measurement filter turned off.

Figure 6 shows the **Digital Demodulation Properties** window. The lower half of this display is for the equalization filter. Detailed descriptions for each of these parameters can be found on the following pages. To reset the equalization filter at any time, check the **Reset Equalizer** button.

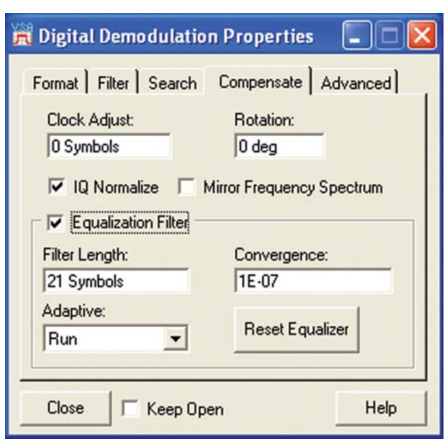

Figure 6. Setting equalization filter parameters for Qpsk.dat signal.

Filter length

The **Filter Length** parameter sets the filter length for the equalizer in terms of symbols. The shorter the filter length, the faster the filter will converge. Filter length should be kept as short as possible for your measurement needs. If you are measuring directly at the transmitter, filter lengths as short as a few symbols can be used. However, if you are measuring at the receiver and multi-path effects are present, much longer filter parameters may be needed to compensate for delays in the signal path. The preset value of 21 symbols, which is used in this demonstration, is a good starting point. It can be adjusted depending on your needs.

Convergence

The **Convergence** parameter sets the size between steps of the filter coefficients when the filter is being shaped. In practicality, this dictates how quickly the filter will converge to the correct shape. Values that are too small cause the filter to converge very slowly, making the wait time for the filter impractical. However, if values are too large you will not be able to minimize EVM error. The best approach is to start with a larger value and step down to reasonable values. Typically, a good convergence value is approximately 1E-7. Figure 7, below, shows the resulting 'blow up' effect of a convergence value set to 1E-5, which is too large. This same effect will occur even when using a reasonable convergence value if the equalizer is left to continuously run for an extended amount of time (10+ minutes for this signal with the given parameters). This is a phenomenon that occurs with all blind equalization filters, as the filter is not using a training sequence, and begins to 'over-correct' the filter coefficients.

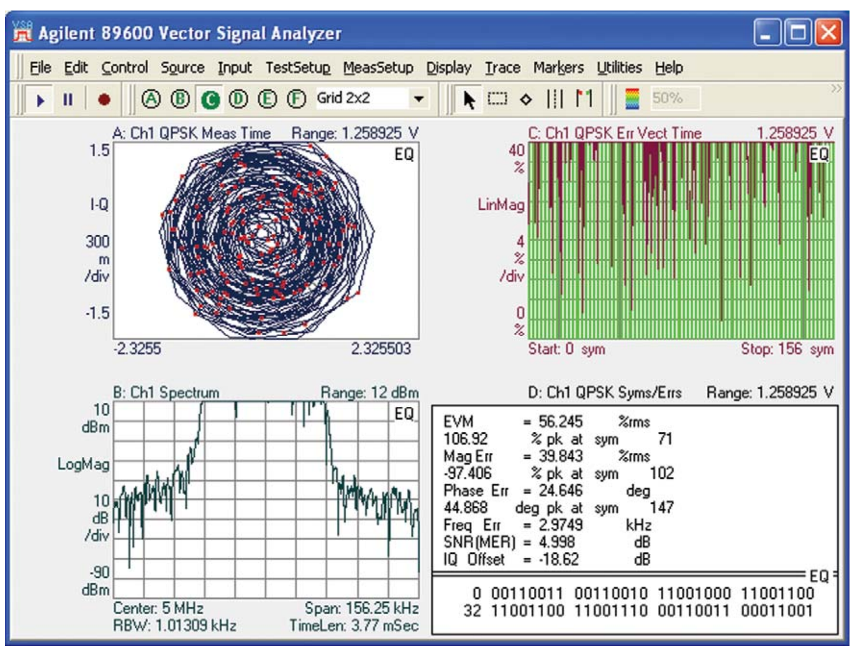

Figure 7. Qpsk.dat signal with convergence value set to 1E-5. Note that the same 'blow up' effect occurs if the equalizer runs for a long period of time.

Adaptive

The **Adaptive** parameter determines whether or not the adaptive equalizer is actively computing new values for the filter. If the **Run** selection is chosen, new values are actively being computed, and then applied to the filter. In this manner, the filter is continuously adapting to changes it "sees" in the output. If the **Hold** selection is chosen, the last computed filter coefficients are being used in the equalization filter, but new values are not being computed.

Table 5. Turning on the adaptive equalizer

Instructions	Toolbar menus
Turn off the Measurement Filter. Note that the constellation is now poorly formed.	Click the **Filter** tab Click the drop-down arrow for **Measurement Filter** and select **Off**
Turn on the Equalization Filter	Click the **Compensate** tab Click in the box next to **Equalization Filter**
Set the Equalization Filter parameters	In the **Filter Length** box type **21** In the **Convergence** box type **1E-7** Click the drop-down arrow for **Adaptive** and select **Run** Click the **Reset Equalizer** button

Figure 8 and Figure 9, on page 11, are screen shots of the equalizer at two different times. Figure 8 was taken immediately after the equalizer began running, while Figure 9 was taken a little over a minute later. In these figures, **Trace C** shows the error vector time display, which is error vector magnitude (EVM) vs. time, and **Trace D** shows the EVM error, along with several other measurements. Notice that in Figure 8 the error magnitude is larger than that of Figure 9, both graphically in **Trace C** and the numeric EVM measurement in the **Error Summary Trace** of **Trace D**. You can observe this phenomenon by clicking the **Reset Equalizer** button again and watching **Trace C**. Over time you will see the effects of the adaptive equalizer take effect and significantly decrease this error. You should also notice in these figures that 'EQ' appears in the upper right hand corner of each display. This indicates that the equalization filter is active.

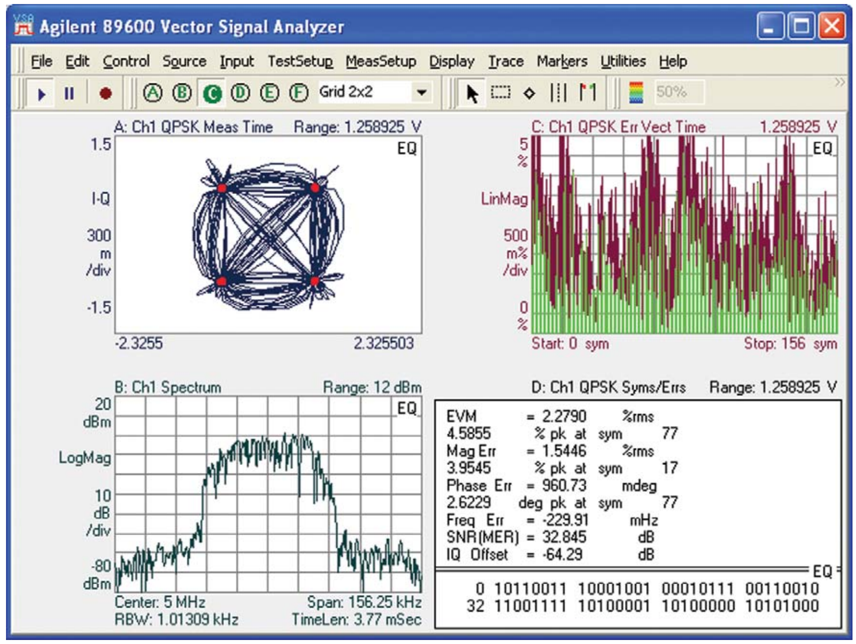

Figure 8. Note the high EVM vs. Time in Trace C (upper right) at start of equalization.

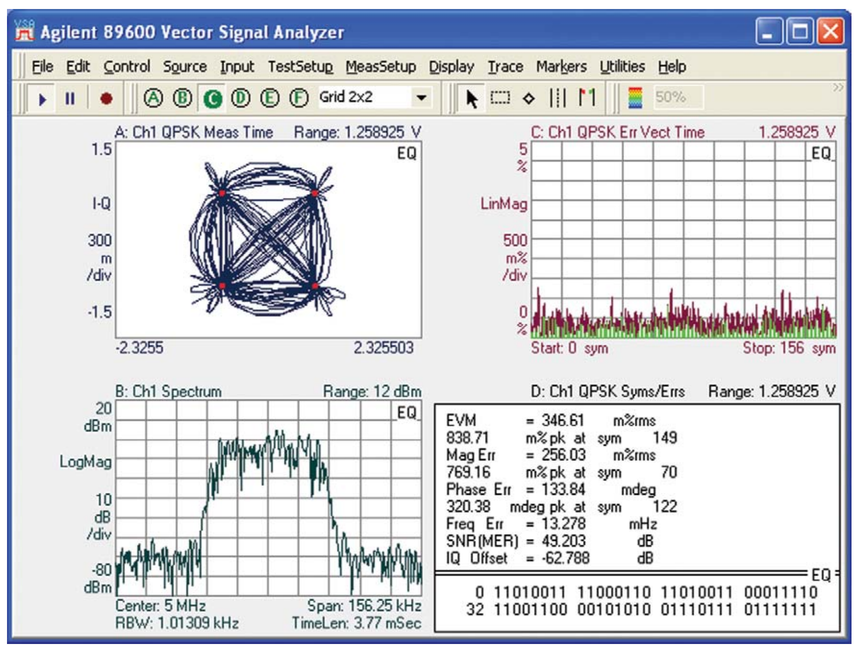

Figure 9. Low EVM vs. Time after allowing equalizer to run (Trace C, upper right).

Trace displays

There are several trace displays that can be used to view the filtering that the adaptive equalizer provides. The steps to view these traces are outlined in Table 6. The data from these traces can be captured for export to a spreadsheet by selecting the trace (by left clicking anywhere in the trace), then clicking **Edit > Copy Trace Data**. Use this to create your own filters by copying the equalizer impulse response and using its coefficients.

Channel frequency response

The **Ch Frequency Response** display shows the channel frequency response of the channel being measured. It is computed by taking the inverse of the of the equalization filter's frequency response. It is typically used to evaluate transmitter and/or receiver multi-path effects. Trace **B** in Figure 11 gives an example of the channel frequency response.

Equalizer impulse response

The **Eq Impulse Response** display shows the time domain response of the equalization filter. Initially, or on reset, the **Eq Impulse Response** display shows a unit impulse response. Once the filter has been turned on, however, the adaptive equalizer modifies the coefficients and the impulse response is changed to "clean up" the signal.

Table 6. Equalization displays

Instructions	Toolbar menus
Channel Frequency Response display	Double click the **Trace B** title (**B: Ch1 Spectrum**) Select **Channel 1** from the **Type** menu Select **Ch Frequency Response** from the **Data** menu Click **OK**
Symbol Table display	Double click the **Trace C** title (**C: Ch1 QPSK Err Vect Time**) Select **Channel 1** from the **Type** menu Select **Syms/Errs** from the **Data** menu Click **OK**
Equalizer Impulse Response display	Double click the **Trace D** title (**D: Ch1 QPSK Syms/Errs**) Select **Channel 1** from the **Type** menu Select **Eq Impulse Response** from the **Data** menu. Click **OK**
Reset the equalization filter	Click the **Reset Equalizer** button
Auto scale Trace B	Right click anywhere in **Trace B** Select **Y Auto Scale**
Auto scale Trace D	Right click anywhere in **Trace D** Select **Y Auto Scale**

Figure 10 and Figure 11 show several different stages of the equalizer response as it modifies the filter coefficients. Figure 10 shows the initial response of the equalization filter when it first starts running. Figure 11 shows the equalizer's response after a little over a minute, which is approximately the optimal value.

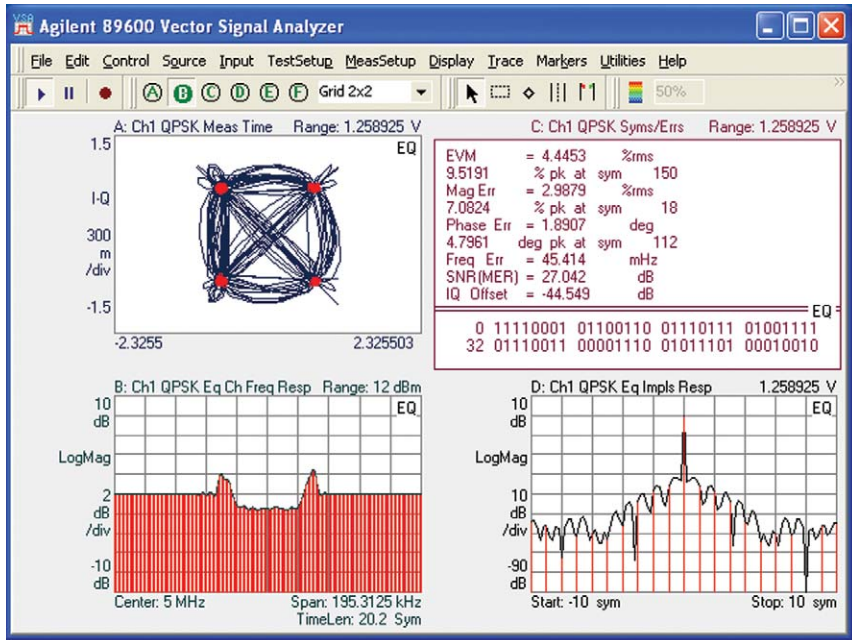

Figure 10. Beginning of digital demodulation for Qpsk.dat signal. Note that the equalizer channel frequency response (trace B, lower left) is only slightly varied from its initial flat response.

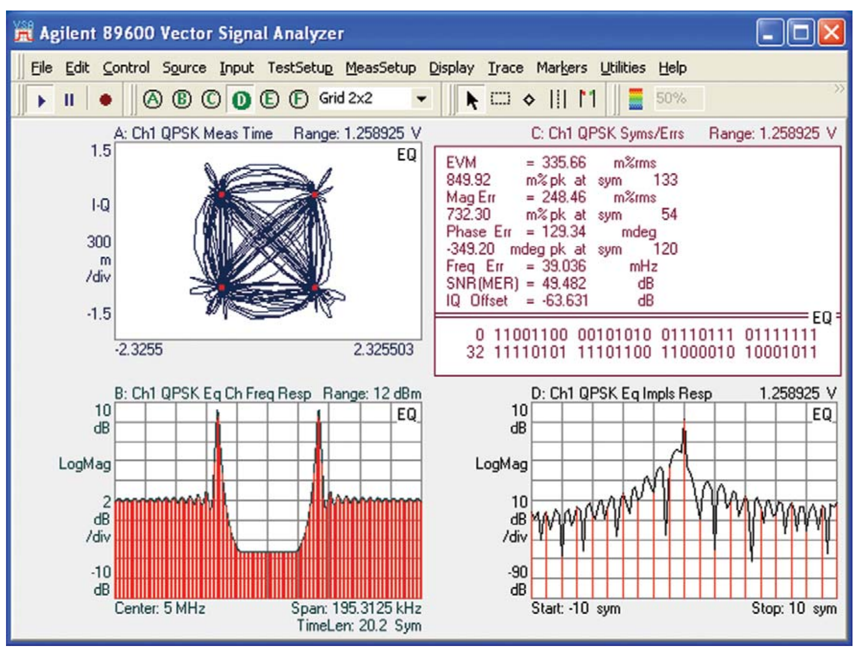

Figure 11. Digital demodulation for Qpsk.dat signal after about a minute, with excellent EVM (see Trace C table), and well-formed channel frequency response.

Summary

Making measurements on digitally modulated, burst, or hopping signals can be difficult. Agilent's 89600 VSA software can help aid you in troubleshooting your signals so you can make your measurements quickly and easily. The adaptive equalizer that is a standard feature in the vector modulation analysis Option AYA is an invaluable tool to help measure and troubleshoot your signal. With preset modes, and table summaries of common measurements, the 89600 VSA software is the perfect tool for any designer wanting a competitive edge in getting their product to market faster.

Related Literature

Publication title	Publication type	Publication number
89600 Series Vector Signal Analysis	Technical Overview	5989-1679EN
89600 Series Vector Signal Analysis 89601A/89601AN/89601N12	Data Sheet	5989-1786EN
89600 Vector Signal Analyzer demo software	CD	5980-1989E
Equalization Techniques and OFDM Troubleshooting for Wireless LANs	Application Note	5988-9440EN
Hardware Measurement Platforms for the Agilent 89600 Series Vector Signal Analysis Software	Data Sheet	5989-1753EN
89600 Series Vector Signal Analyzers, VXI	Configuration Guide	5989-9350E
89607A WLAN Test Suite Software	Technical Overview	5988-9574EN

Web Resources

For additional information, visit:

www.agilent.com/find/89600

Ordering Information

89601A or 89601AN	**Vector signal analysis software 89601A (node-locked license) also includes 1 year of software update subscription service. 89601AN (floating license) has a software update subscription service available for order separately.**
Options	Options 200 and 300 are required
• -200	Basic vector signal analysis software
• -300	Hardware connectivity
• -AYA	Flexible modulation analysis
• -BHD	LTE modulation analysis
• -B7N	3G modulation analysis bundle
• -B7T	cdma2000®/1xEV-DV modulation analysis
• -B7U	W-CDMA/HSDPA modulation analysis
• -B7W	1xEV-DO modulation analysis
• -B7X	TD-SCDMA modulation analysis
• -B7R	WLAN modulation analysis
• -B7S	IEEE 802.16-2004 OFDM modulation analysis
• -B7Y	IEEE 802.16 OFDMA modulation analysis
• -B7Z	IEEE 802.11n modulation analysis
• -BHA	TETRA modulation analysis and test
• -BHB	MB-OFDM ultra-wideband modulation analysis
• -BHC	RFID modulation analysis
• -105	Dynamic link to EEsof/ADS
• -106	Dynamic link to The MathWorks Simulink Model-Based Design

89601N12	**Vector signal analysis software, 12-month limited-term package floating license for one server; includes 1-year software update subscription.**
Options	*Required. Multiple 801 options may be ordered per server.* *For multiple servers, order additional 89601N12.*
89601N12-801	Twelve-month floating license software package including VSA software Options -200, -300, -105, -106, -AYA, -B7N, -B7R, -B7S, -B7Y, -B7Z, -BHA, -BHB, -BHC, -BHD

89601AS	**Additional software update subscription service**
Notes	Twelve-month minimum required. Twenty-four-month maximum coverage, total. 1-year is provided. Model 89601AS is available for upgrade or renewal orders only. To order, choose the number of months desired, and order Option 89601AS-0xx, where xx is 12 to 24, corresponding to the number of months of coverage desired. See www.agilent.com/find/89600 and click "Software Update Subscription Service" for descriptions of actual product and option structure.

89601ASN	**Software update subscription service for one server (floating license)**
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